Ocean Quahaug Survey, South Shore of Nova Scotia, 1971-72, With Observations on a Preliminary Survey by SCUBA and a Commercial Fishery

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OCEAN QUAHAUG SURVEY, SOUTH SHORE OF NOVA SCOTIA, 1971-72, WITH OBSERVATIONS ON A PRELIMINARY SURVEY BY SCUBA AND A COMMERCIAL FISHERY

by

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FOREWORD

Under the direction of Dr. J. C. Medcof, and with the cooperation of Triton Sea Products Ltd., Port Medway, N.S., observations on ocean quahaug populations and on commercial fishing practices and gear efficiencies were made in 1971 and 1972. Gear efficiency studies were given priority at that time and reported to the International Council for the Exploration of the Sea (Medcof and Caddy 1971) soon after work was completed. The population data were to be considered later.

With renewed interest in ocean quahaug distributions in both Nova Scotia's inshore and offshore areas, it seemed appropriate at this time to assemble these data in a more accessible form.

Valuable distribution data and comments on the commercial fishery were submitted by Fred Libby, a geologist with Triton Sea Products Ltd., who, while exploring for placer gold along Nova Scotia's south shore, discovered how vast the quahaug resources were in that area. As well, Paul Haughton, captain of the commercial quahaug dredger, BLUE SWAN, made many constructive observations on towing techniques, gear specifications and quahaug distributions. Our work program was greatly influenced by their observations which, with their permission, are reported here.

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ABSTRACT

Chandler, R. A. 1983. Ocean quahaug survey, south shore of Nova Scotia, 1971-72, with observations on a preliminary survey by SCUBA and a commercial fishery. Can. MS Rep. Fish. Aquat. Sci. 1726: iv + 28 p.

The discovery of a large resource of ocean quahaugs (Arctica islandica) along the south shore of Nova Scotia, followed by a SCUBA survey to determine their commercial potential, resulted in a brisk, but brief, fishery based at Port Medway, N.S., in 1970-71. This commercial activity prompted us to make population studies by hydraulic dredge in 1971-72.

Population density and abundance estimates were determined from the SCUBA survey, the 1972 dredge survey, and commercial catch data. Ocean quahaugs were commercially abundant in the La Have River estuary, False La Have, Medway Harbour, Green Bay, and Shelburne Harbour; as well, high abundances were found in Shag Harbour. Most quahaug beds were in 13-20 m on hard-packed sand bottom on which only hydraulic dredges could be used efficiently. Since survey tows in Jordan Bay and outer Liverpool Bay were made with dry dredges, only the presence of quahaugs could be established there.

Although the substrate varied from rock and coarse gravel to sand and silty clay, sediment analysis based on the Wentworth scale showed that most areas had a medium to fine sand substrate.

Cherrystone (6.4-7.6 cm) and chowder (>7.6 cm) quahaugs were the predominant sizes available for commercial use, and growth rates in Shelburne Harbour indicated it would take approximately 16 yr for ocean quahaugs to reach the minimum size of a cherrystone.

Key words: Arctica islandica, hydraulic dredge, dry dredge, sediment, substrate, Wentworth scale, commercial fishery, Nova Scotia, abundance, density

RÉSUMÉ

Chandler, R. A. 1983. Ocean quahaug survey, south shore of Nova Scotia, 1971-72, with observations on a preliminary survey by SCUBA, and a commercial fishery. Can. MS Rep. Fish. Aquat. Sci. 1726: iv + 28 p.

La découverte d'abondantes ressources de palourdes de mer (Arctica islandica) le long de la côte sud de la Nouvelle-Ecosse, suivie d'un relevé par plongeur autonome dans le but d'en déterminer le potentiel commercial, a donné naissance à une pêche active mais brève depuis Port Medway (N.-E.) en 1970-71. Cette activité commerciale nous a incité à mener une étude à l'aide d'une drague hydraulique en 1971-72.

La densité de population et les estimations d'abondance ont été déterminées par relevé en plongée autonome, par le relevé à la drague de 1972, et à partir des données des prises commerciales. La palourde de mer est commercialement abondante dans l'estuaire de la rivière La Hève, False La Have, havre Medway, baie Verte et hâvre Shelburne; on en a également trouvé de fortes quantités à Shag Harbour. La plupart des lits de palourdes de mer se trouvent sur fonds de sable bien tassé, à des profondeurs de 13-20 m, sur lesquels seules les dragues hydrauliques peuvent être utilisées efficacement. Etant donné que des dragues ont servi aux relevés de la baie Jordan et de l'extérieur de la baie Liverpool, on a pu déterminer seulement la présence des palourdes de mer à ces endroits.

Bien que le substrat ait varié de roches et gros gravier à sable et argile vaseuse, l'analyse des sédiments d'après l'échelle de Wentworth démontre que la plupart des zones ont un substrat de sable variant de moyen à fin.

Les palourdes "cherrystone" (6,4-7,6 cm) et de chaudrée (>7,6 cm) sont les tailles prédominantes qui peuvent être utilisées commercialement, et les taux de croissance dans le havre Shelburne indiquent qu'il faudrait environ 16 ans à la palourde pour atteindre la taille minimale de "cherrystone".

INTRODUCTION

Ocean quahaugs occur in many areas in the North Atlantic. On the European side they are found from Norway to the southwest coast of Spain and around the British Isles (Nicol 1951). They are especially abundant around Iceland where they were once an important source of food for native Icelanders, hence the name Arctica icelandica. Along the eastern coast of North America they occur from Newfoundland to North Carolina (Merrill et al. 1969). They are found in sediments varying from hard-packed sand to soft mud and, as they are a coldwater species, are generally found in deep water, especially towards the southern limits of their range.

The presence of ocean quahaugs along the south shore of Nova Scotia has been known for many years. To my knowledge, the earliest Canadian attempt to fish for ocean quahaugs was made during the 1920's by Capt. McKenzie Bower of Jordan Bay, N.S. After finding quahaugs in his lobster traps and attached to his groundlines, Capt. Bower built a small dry dredge and, by towing it behind a gasoline-powered boat, succeeded in capturing small quantities which he used for baiting his longlines (P. Bush, pers. comm.).

Brief surveys were made in Medway Channel in 1956 (Medcof 1957, 1974) and in Shag Harbour in 1966 (Medcof et al. 1969). Both surveys confirmed the presence of quahaugs in those areas, but the extent of this resource remained unknown.

In the late 1960's, Fred Libby, an associate of Triton Sea Products, found large concentrations of quahaugs while exploring for gold along Nova Scotia's south shore. He subsequently made population density counts, using SCUBA in the La Have River estuary, False La Have, Medway Harbour, outer Liverpool Bay, and Shelburne Harbour. His findings are summarized in this report.

Following Libby's discovery, a substantial, although somewhat brief, fishery was based at Port Medway, N.S., where annual catches in 1970 and 1971 were 400 and 918 metric tons (MT) round weight, respectively. Comments on distribution and catch rates made by the skippers of the commercial dredgers BLUE SWAN and GENERAL PAGE have been used in this report to assess populations in several areas.

This commercial interest in ocean quahaugs (or "ocean clams", the name commonly used by industry at that time) prompted us to initiate fishing gear studies and population assessments along that coast in July 1971, and May 1972. The 1971 gear studies determined the efficiency of both dry and wet (hydraulic) dredges and concluded that dry dredges used in this area of predominantly hard-packed sand bottom were very inefficient (<1%) and most destructive to quahaugs in their path. Our small hydraulic dredge was 76% efficient and the large commercial hydraulic dredge was over 90% efficient (Medcof and Caddy 1971).

Ocean quahaugs are slow growing and, although growth rates were not known for the south shore area, it was estimated from growth studies in Passamaquoddy Bay, N.B., that it would take approximately 16 yr for a specimen to reach the minimum size of a cherrystone quahaug (6.4 cm) (Meagher and Medcof 1972). At this slow rate of stock renewal, a fishery would need a large resource base to ensure a stable supply. We therefore undertook to assess populations which were in close proximity to the newly established commercial operation.

From commercial sources we knew that quahaugs were abundant in several inlets and realized the tremendous advantage this would give an industry based on what is usually a deep water, offshore species. If quahaugs could be found in abundance offshore as well, an uninterrupted year-round supply could be guaranteed by fishing offshore during good weather, thus saving the inshore stocks for winter harvesting. Therefore, with the above in mind, our objectives were 1) to determine gear efficiencies, 2) to assess population distribution of inshore stocks along the south shore, 3) to discover the parameters, such as sediment characteristics, water temperatures, and salinities, controlling this distribution, 4) to survey areas offshore from harbours which have abundant populations, and 5) to explore inlets along the "eastern shore" of Nova Scotia.

This report deals primarily with the south shore population survey and gives a brief account of preliminary fishing trials carried out at Seal Cove, Grand Manan, N.B., in May 1971. As well, we have attempted to compile and analyze data gathered from commercial sources to make that information more generally available to those considering commercial exploitation of the resource.

SURVEY MATERIALS AND METHODS

EQUIPMENT

The 24-m (109 GT) research vessel M.V. HARENGUS was used with two basic types of dredges: in 1971 we used the "Bush" dry dredge, and a small hydraulic dredge which we called the hydraulic "sampler"; in 1972, we used a larger version of the "sampler." Both hydraulic dredges were built at the St. Andrews Biological Station and were similar to, but smaller than, the Long Island-type hydraulic dredge which was used successfully in earlier surveys in Northumberland Strait (Chandler 1965). All dredges were lined with 2.5-cm stretched mesh netting.

The "Bush" dredge

This dry dredge (Fig. 1) was built by Percy Bush of Sandy Point, N.S., and resembled in configuration the much larger commercial hydraulic dredge used in that area. It was a rigid metal cage, 18 cm high at the mouth, increasing to 43 cm at the rear, and was 2.3 m long and 1.4 m wide. The bottom was closed in with rods 1.9 cm in diameter spaced 2.5 cm apart. The toothed mouth was of the same construction as the dredge's bottom and was 97 cm wide and could dig 18 cm into soft bottom. The sides and top of the cage were closed in with heavy gauge wire mesh with 4.3-cm openings. It had a hinged rear door for dumping.

The hydraulic dredges

The hydraulic "sampler" (Fig. 1) was 0.4 m wide at the front where the manifold and digging blade were located, widening to a 0.9-m wide and 0.8-m long holding cage. The overall height was 25 cm. Its metal frame was closed in with 1-cm diameter

iron rods spaced 2.5 cm apart. A hinged dumping door was at the rear. Its digging blade had a forward edge made of 1-cm thick flat iron to which was welded a series of 1-cm rods spaced 2.5 cm apart and leading back to the cage portion of the dredge. This blade was 29 cm wide and could dig up to 13 cm. Lead weights (27 kg each) were mounted on each side at the front of the dredge, making a total dredge weight of 180 kg.

A 15-cm diameter manifold was located above and slightly ahead of the blade. Four nozzles located in the manifold directed jets of water under pressure approximately 5 cm in front of the leading edge of the blade. In addition, three longer nozzles directed water back towards the entrance of the cage to help clear away piled up debris and mud.

The larger, 1972 hydraulic dredge was 0.5 m wide at the front, flaring out to the holding cage 1.2 m wide and 1.8 m long. Two types of digging blades, each 41 cm wide, could be used with this dredge. A toothed blade made of 1.3-cm iron rods, sharpened at the digging end, and spaced 2.5 cm apart, could be interchanged with a lip blade similar to that used on the "sampler." Five nozzles in the manifold directed jets of water toward the digging blade.

Water pressure was usually at 2.8 kg/cm^2 (40 psi) and was supplied by a Monarch centrifugal pump with a rated capacity capable of delivering 1350 L of water per minute (357 gal/min). The pump was driven by direct hookup to a 4-cylinder, 24-hp Wisconsin gasoline engine. Both units were mounted on a common platform rigged with a cable bridle for conveniently moving on and off boats. This unit was bolted to the port deck of the HARENGUS, while the dredge, with its accompanying fire hose and tow rope, was worked from the starboard side.

A 10-cm diameter intake hose 4.6 m long, with a foot valve installed, supplied water to the pump and a 6.4-cm diameter fire hose carried water from the pump to the dredge manifold.

DRAGGING PROCEDURES

The hydraulic dredge was towed at 0.5-2.0 knots with a 1.9-cm polypropylene rope and was retrieved with a wire cable. The ratio of tow rope to water depth was 2.5-3:1 and, as suggested by Paul Haughton, captain of the commercial dredger, BLUE SWAN, 15 m of fire hose were used for every 11 m of tow rope. The dredge was set with the boat moving slowly ahead while the fire hose was played out over the stern to prevent fouling in the propeller. A low water pressure to the manifold was maintained while the dredge was being lowered and, as the tow began, pressure was increased to the desired level. At the end of the tow, the pump was shut off once the dredge left bottom.

The "Bush" dredge was towed with a 0.9-cm wire warp fastened to the foremost towing point on the dredge (otherwise, it would flip onto its back as soon as the teeth dug into the bottom). Tow duration was 10-15 min with speed between 1-2 knots.

During the 1971 survey tow distance was not recorded; however, tow duration was 10-20 min with starting locations determined from land fixes and plotted on harbor charts. Sampling stations were often located in areas suggested by local fishermen to be promising places to find quahaugs.

In 1972, transects were established in three of the four areas surveyed. A primary transect ran roughly in mid channel from the entrance to the head of an inlet. Secondary transects running along either side of, and across, the main one were used in several areas. Stations were placed at each end of the transect and at the at mid point, and intermediate stations were added as required for better understanding of distribution patterns. No set distance was established between stations. Duplicate tows were made at each station and tow distances were precisely defined by setting out two buoys with anchors separated by a 183-m (200-yd) ground line.

MEASUREMENT OF CATCH

The total catch of live quahaugs was recorded in bushels and/or numbers, with broken and whole animals recorded separately. The shells of quahaugs are very brittle and it was discovered early that extensive breakage occurred during dredging (17%) and while being dumped on deck (8%) if the catch was dumped carelessly (Appendix I). This dumping breakage factor was subtracted from the number of broken quahaugs when gentle dumping was impossible.

Shell length frequencies were determined in 5-mm increments for each station. Shell length was defined as the measurement of the longest axis and shell height as the longest measurement from the umbone to the shell margin (Fig. 2).

MISCELLANEOUS OBSERVATIONS

Shells were saved from 12 quahaugs representing the size range and predominant color of the animals caught at each station. These were to be studied for growth rates and to determine if color and the extent of surface abrasion of the shells were related to type of substrate and location of the beds.

A Knudsen reversing water bottle was used to take bottom water temperatures along with salinity samples at the surface and at 2.4-m (8-ft) depths.

Substrate samples were collected at each station by SCUBA or cone dredge and stored fresh. These samples were later dried for 1 h at 400°C, after which sand clumps were broken up with a pestle and sifted through a series of six sieves on a series of six sieves on a shaker at medium speed for 10 min. The sieves corresponded to the Wentworth grade classification as follows:

Sieve mesh size (mm)	Wentworth No. (Ø)	Substrate description
2.0	-1	granules
1.0	0	very coarse sand
0.5	1	coarse sand
0.25	2	medium sand
0.125	3	fine sand
0.063	4	very fine sand
pan		silt and clay

The contents of each sieve were recorded by weight and volume. Cumulative percentages by grain size were calculated and plotted for each sample. The median grain size (size at 50%) was then determined from each plot.

AREAS STUDIED

Preliminary trials were conducted in Seal Cove Sound, Grand Manan, where 12 tows were made with both dry and wet lined dredges. The bottom was much too hard for the dry dredge as its teeth dug only 4-5 cm into the sediment. Catches up to 1 bu (.04 m^3) were made with the hydraulic sampler once towing speed was adjusted properly to the digging rate of the dredge. The positions for tows 1-11 were in the same area and described as "being 330 yd (302 m) long, in 42 ft (13 m) of water, and passing within 25 ft (8 m) of the back of the Nubble weir at mid tow." Tow 12 was on mud bottom in mid channel (Fig. 3I). Although all quahaugs were small with a mean shell length of 55.5 mm (Fig. 5A) and caught within the confined area of Seal Cove Sound, three distinctive shell colors were found there: straw yellow and dark brown specimens were caught in tows 1-11, and black specimens, which were only slightly larger at a mean of 59 mm, were caught in tow 12.

Eight areas were considered for study along the south shore: the La Have River estuary, False La Have, Green Bay, Medway Harbour, outer Liverpool Bay, Jordan Bay, Shelburne Harbour, and Shag Harbour (Fig. 3). Most areas had some background population data available, either from previous surveys or from commercial sources. The most valuable was Libby's SCUBA survey in which he determined densities by counting the number of quahaugs inside a 0.5-yd^2 (0.46-m^2) steel frame. He described one of his counting techniques as follows: "On my dives, as I approached the bottom I would strike it a good blow with my fist. If the quahaugs were feeding, I could see little puffs of sand all around me as they contracted their shells, exhausting water. This would give me a rough idea of the density and allow me to pick an average looking spot to place my steel frame for density counts."

We surveyed Shelburne Harbour, Jordan Bay and Shag Harbour in 1971, and the La Have River estuary, False La Have, outer Liverpool Bay and, for a second time, Shelburne Harbour in 1972.

RESULTS AND DISCUSSION

A total of 65 survey tows were completed; 24 tows were made in 1971 (Table 1) and 41 tows in 1972 (Table 2). Catch rates and densities were summarized for the dredge surveys and Libby's SCUBA survey (Table 3). The 1972 catch rates were prorated to reflect a 183-m tow.

Abundance estimates were made in five areas: La Have River, False La Have, Medway Harbour, Green Bay, and Shelburne Harbour which was divided into two subareas, the Eastern Way (E.W.) which was principally surveyed by hydraulic dredge (Libby had only one dive site there), and the Western Way (W.W.) which was surveyed only by Libby. All five areas were 1) surveyed in 1972 when tow distances were accurately monitored, 2) had sufficient information on commercial fishing rates, and/or 3) were surveyed by Libby. Estimates were calculated separately from each data source. The locations where quahaugs were found during the 1972 dredge survey and Libby's survey were identified on charts (see shaded areas in Fig. 4) and total areas (km^2), mean densities, and abundance estimates were calculated for them (Table 4). These estimates should be qualified in that 1) the sampling stations were not randomly located, 2) the population boundaries were not conclusively delineated and should be considered as only approximate, and 3) although efficiency studies were not made with the 1972 dredge, it was assumed to have the same factor (76%) as the 1971 dredge since it was of the same design and towed by the same boat.

Abundance estimates determined from commercial catch data were based on the following premises: 1) the area fished per tow by the BLUE SWAN's dredge was 676 m^2 (the digging blade was 1.25 m wide and a typical tow was made for 15-20 min (avg. 17.5) at 1 knot, which is equivalent to an average distance of 541 m), 2) commercial catches were recorded in bushels and it was estimated from our 1971 Shelburne measurements that 1 bu (.04 m^2) of large quahaugs (>80 mm) numbered 250 individuals, 1 bu of medium quahaugs (70-80 mm) numbered 275, and 1 bu of small quahaugs (60-70 mm) numbered 300, 3) the dredge was 90% efficient (Medcof and Caddy 1971) and densities were adjusted upwards accordingly, and 4) commercial beds were outlined on harbour charts by P. Haughton from which their areas (km^2) were determined.

Areas of commercial potential were outlined (by a dashed line) in Fig. 4. They included, in addition to beds described by Haughton, areas where 300 or more quahaugs/tow were caught by the HARENGUS, and/or 10 or more quahaugs/m^2 were found by Libby.

Water temperatures and salinities were taken in four locations (Table 5). Too few observations were made to be of practical value in assessing their influence on distribution patterns. As well, it would have been advisable to collect salinity samples closer to bottom to avoid possible contamination by deep layers of brackish water which occurred in many of the inlets explored.

Shell length-frequency means and modes were summarized (Table 6), and detailed frequencies for individual tows are given by area in Appendix Tables 1A-1F. Measurements of quahaugs caught by the BLUE SWAN at Shelburne and Medway are given in Appendix Table 1G.

Results and observations from all sources are presented by area below.

AREA I - LA HAVE RIVER ESTUARY

We intended to use the toothed blade on our hydraulic dredge in this area; however, the teeth were bent beyond repair on the first tow and we were forced to use the lip blade for the remainder of the survey. We made nine tows at six sites along a transect running the length of the estuary in mid-channel and Libby made 10 dives, mostly in the southern part of the estuary (Fig. 3A). Catch details (Table 2) show that the highest quahaug densities occurred towards the northern end of the transect in 7.3 m of water close to the area where Libby found the highest concentrations of his entire survey at 32/yd^2 (38.3/m^2). The greatest density of our dredge survey was at tow 27 where 26.2 quahaugs per m^2 occurred. Two areas of commercial potential were identified, a 1.9-km^2 area at the head of the estuary and a 1.1-km^2 area at the entrance (Fig. 4).

Abundance estimates determined for the shaded areas in Fig. 4 by Libby (107.8×10^6 quahaugs) were much larger than our estimates (46.6×10^6). This may reflect a spotty quahaug population or a

greater inefficiency in our dredge than anticipated, especially in "sticky mud" areas where the dredge's opening can easily be clogged, i.e. our tows 28 and 29 produced very little, while Libby had a count of 18/yd^2 (21.5/m^2) nearby.

The bottom varied from coarse sand and gravel near the entrance (tows 32 and 33) to silt and silty clay towards the northern end of the transect. Five sediment samples collected had a median particle size of 2.4 Ø (Table 2). Depth of tows varied from 15.2 m at the entrance to 6.1 m at the head of the estuary, with most tows and the largest catches being in 7-7.5 m.

Length frequencies showed a mode at 80-89.9 mm (Fig. 5A). The largest sized animals were taken at tow 25 which had a mode at 85-89.9 mm. Dead shell was common at tow 30. Libby's samples near our tows 28 and 29 showed a "very high concentration of small clams which constituted about 60% littlenecks and 40% cherrystones with an occasional chowder." He described these commercial size categories as follows: "Littlenecks were less than 2 1/2 in. (<6.4 cm), cherrystones between 2 1/2 and 3 in. (6.4-7.6 cm), and chowders greater than 3 in. (>7.6 cm). In addition, there was another category promoted as a gimmick, by Delta Sea Products, N.Y., called bignecks at 2 1/2-2 5/8 in. (6.4-6.7 cm)."

No commercial dredging was done here since the area was legally closed to shellfish harvesting due to high levels of bacterial pollution. Libby made two dives in neighboring Hartling Bay where no quahaugs were found (Fig. 3A).

AREA II - FALSE LA HAVE

This was one of the main commercial harvesting areas in 1971 and a holding facility was built at Bush Island to keep crates of quahaugs live until they were required by the processing plant at Medway. Libby and Haughton believed that quahaug densities were greatest on the eastern side of most inlets and we attempted to investigate this at False La Have.

Three transects were established, two in the direction of the channel and one across it, and 21 tows were made on 11 sites (Fig. 3B). Largest catches were in mid channel in 6.1 m of water at tows 42 and 43 where densities averaged 11.4/m^2 (Table 2). Libby made 17 dives and found quahaug distributions similar to ours with the higher densities occurring from mid channel towards the eastern shore of the inlet. The entrance was too rocky to dredge; consequently, tows 40 and 41 caught very little, although Libby counted 28/yd^2 (33.5/m^2) on a nearby diving site. Quahaug abundance estimated from Libby's survey was 21.1 x 10^6 for a 1.4-km^2 area, nearly four times our estimate of 5.9 x 10^6 for 1.3 km^2 (Table 4). Our densities were consistently lower than those observed by Libby and could largely be due to the fact that Libby's survey was made prior to commercial fishing in this area while ours was made after. Libby observed that they harvested several thousand bushels from False La Have before stocks began to wane; for example, a spot just south of the west end of Mosher Island produced an average of 16/yard^2 (19.1/m^2) in the fall of 1969 and again in the summer of 1970. A 0.8-km^2 area was identified as being of commercial significance (Fig. 4).

Libby noted the average sample from False La Have constituted about 5% littleneck, 60% cherrystone and 35% chowders, and that most of the quahaugs were of the same appearance, having a mahogany colored epidermal covering, although there was an occasional one up to 10.2 cm with a partial black epidermis. Our length frequency measurements showed a sharp mode at 65-69.9 mm (Fig. 5A) with very little variation from one station to another.

The entire inlet was quite shallow with the deepest tows (40 and 41) being at the entrance in 7.9 m. Most tows were in 6-7 m where the largest catches occurred.

Sediment samples were taken on all sites except tow 44 (Table 2) where the bottom appeared to be hard-packed sand with a silt bank running through it. Bottom type varied from coarse sand and rock at the entrance to sand and silty sand in the central part of the inlet where sand dollars were in abundance. Silt was common at the head of the inlet (tow 52).

Libby found that medium sands in this area yielded the highest densities while coarse grain sands and silt areas yielded few or no quahaugs. He saw no quahaugs in sand dunes or ripple areas, and felt this may be related to grain size or currents associated with these substrates. The currents were apparently too strong in the coarse sand areas or too gentle in the silt areas, whereas quahaugs seem to prefer a moderate current in areas of medium grain size and fairly stable bottom.

In some areas of strong currents he found quahaugs "sitting on top of the sediment as if they had been excavated and left helplessly stranded, making no attempt to bury themselves. These were usually the chowder sizes." Similar "washouts" were also observed by commercial diver Rudolph Link, of Clark's Harbour, N.S., who, while diving in Shag Harbour in August 1966, saw large numbers of ocean quahaugs lying in "windrows" on the bottom (Medcof et al. 1969).

AREA III - GREEN BAY AND CRESCENT BEACH

No survey was done here but Haughton stated that quantities of large quahaugs were fished commercially along the eastern side of this bay in 5-6 fm (9.1-11.0 m) (Fig. 3C) where the BLUE SWAN caught 175-180 bu/d (7-7.2 m^3/d). Assuming a count of 250 quahaugs/bu, a total abundance was estimated at 8.8 x 10^6 for this 1.4-km^2 bed (Table 4). Libby stated that "the east Green Bay area was very productive, with unusually large sizes being landed. This area had few or no littlenecks. Densities decreased toward Crooked Channel where the bottom was mostly silt. The dredge did not work too well there as it filled with silt and would not allow new material to enter. Quahaugs were very easy to dig by hand (SCUBA) compared to sand areas and were a weak yellow color and muddy tasting."

Libby found surf clams in the Crescent Beach area and estimated that there were 8-10/yd^2 (9.6-12/m^2). "There is about 1.1 mi (1.8 km) of beach where surf clams may be dug at low tide. Surprisingly, nobody in that area knew there were clams along that beach even though seagulls dug them at low tide and opened them by dropping them on the hard sand." Libby dug by hand 20-30 surf clams in

half an hour along the entire length of the beach, and by using the small hydraulic dredger at high tide, 4 bu (.16 m^3) per 5-min tow were collected. The clams were relatively small, having an average size of 11.4 cm. He tried digging some at low tide when the surf was running high but was unsuccessful and concluded that they must go deep when the surf is very active. The dredge was unable to catch any in deeper waters off the beach, and therefore he felt they must be concentrated in the shallow waters only.

Libby made a dive east of Crescent Beach and one in Crooked Channel and found nothing (Fig. 3C).

AREA IV - MEDWAY HARBOUR

This area was not included in our survey; however, it was the principal harvest area at the beginning of plant operations at Port Medway. Libby stated that catches were constant from this area and "the boat skippers swore that the clams must be 10 ft (3.0 m) thick there because they could work between two buoys day after day without a reduction in catch." The small dredger, GENERAL PAGE, consistently landed 100 bu/d (4 m^3/d) but found that a great deal of sorting was required as roughly half the catch was dead shell.

The main commercial bed was east of an underwater cable which goes roughly down the middle of Medway Channel. Commercial catches were 16-18 bu/tow (.64-.72 m^3/tow) on this bed while a bed west of the channel produced 10-11 bu/tow (.40-.44 m^3/tow) (Fig. 3D). From these catch rates it was estimated that the two beds, with a total area of 1.0 km^2, had an estimated abundance of 5.6 x 10^6 (Table 4).

Libby made 10 dives in Medway Harbour and found the highest densities to be in mid channel where counts were up to 18/yd^2 (21.5/m^2). An estimated abundance of 63.8 x 10^6 quahaugs were in the 4.4-km^2 channel area (shaded area in Fig. 4) at the time of Libby's survey (Table 4) but were not fished effectively due to the proximity of the underwater cable. A 3.2-km^2 area was identified as being commercially significant (Fig. 4).

Haughton considered clams from here to be small compared with other commercial fishing areas. However, we measured an unculled sample of their catch and found them to be large with a mode at 80-89.9 mm which fell between the two modes found in the catch of the BLUE SWAN at Shelburne (Fig. 5B). Quahaugs from this area were considered best for the half shell trade where light-colored shells were favored.

In the summer of 1971 we studied commercial dredging by the BLUE SWAN. A brief underwater film was made of the dredge in action and efficiency studies were conducted. The Canadian Navy supplied a submersible and divers to assist in this program. Our underwater observations revealed that high quahaug mortalities occurred during haul-back of the dredge. The usual practice during haul-back was to continue to tow slowly as the dredge was being freed from bottom. Consequently, the teeth and the heavy tail-end of the dredge crushed great numbers of quahaugs living close to the surface. We suggested that towing be stopped during haul-back.

A sediment sample was collected by SCUBA on the western bed where the bottom was hard-packed sand and the median grain size was 2.3 Ø.

Libby made one dive in neighboring Hell Bay where he found one quahaug, and subsequent commercial dragging resulted in low catches on rocky bottom (Fig. 3D).

AREA V - OUTER LIVERPOOL BAY

Three 10-min tows were made near the Sow and Pigs ledge (Fig. 3E); however, due to the excessive water depth of 27.4 m (too deep for hydraulic attachments) and hard bottom, sampling in this area was unsuccessful. Libby made three dives, one in Liverpool Bay which was closed due to bacterial pollution, and two outside the bay near the Sow and Pigs ledge where he found high densities up to 22/yd^2 (26.3/m^2). He stated: "We found large quantities of very small quahaugs in this area. They were so small that most of them filtered through the openings of the dredge (1.9 cm). As the dredge surfaced, one could see 8-10 bu in the basket with a long trail of clams escaping between the bars. Usually, we were able to land only 1-2 bu."

Libby made one dive in the entrance to Blueberry Bay and found nothing. The BLUE SWAN made several earlier tows between Coffin Island and the mainland and found relatively few quahaugs.

AREA VI - JORDAN BAY

Tow sites in this bay (Fig. 3F) were suggested by Percy Bush, who was familiar with quahaug distributions there. Six tows were made with his dry dredge in silty sand (Table 1). However, it appeared the dredge had the same shortcomings found during gear trials in Shelburne Harbour. Consequently, catch results are only indicators of the presence of quahaugs.

AREA VII - SHELBURNE HARBOUR

Nine survey tows (#1-#9) were made east of McNutt Island (the Eastern Way) in 1971 in depths ranging from 6.1-10.0 m (Fig. 3G). Length frequencies taken from five tows showed a wide size range with a mean at 76.8 mm (Table 6). A special tow (#6) was made on silt bottom above Lower Sandy Point wharf and had an unusually high abundance of small quahaugs with a mode of 40-44.9 mm. This tow was made specifically to capture small quahaugs and we were directed to it by P. Haughton. When all tows were combined there were two modes at 40-44.9 mm and 75-79.9 mm; however, without tow 6 there was a single mode at 75-79.9 mm (Fig. 5A). A sample of the commercial catch of the BLUE SWAN taken on the Lower Sandy Point bed, had a mean at 83.5 mm (Table 6) with two modes at 70-79.9 mm and 95-99.9 mm (Fig. 5B).

In 1972, 10 tows (#56-#65) at an average depth of 9.4 m were made on two transects established in the Eastern Way, one running from the entrance northward to a position off Sand Point, and a second one running across the harbour, bisecting the first (Fig. 3G). Shell lengths were measured for 8 of the 10 tows (Fig. 5A). Tow 56, near the harbour entrance was the deepest at 18.3 m and had the highest density (20.1/m^2). The smallest densities occurred at the northern and western ends of the transects. Mean density in the 9.9-km^2 area surveyed in the Eastern Way was 3.3/m^2 (Table 3) with an estimated abundance at 65.3 x 10^6 (Table 4). A 5.4-km^2 area was identified as having commercial potential (Fig. 4).

Our survey did not include the area southwest of McNutt Island (the Western Way) where Libby made eight dives and found high densities up to 20/yd^2 (23.9/m^2) (Fig. 3G) with a mean at 14.4/m^2 (Table 3). An estimated 54.7 x 10^6 quahaugs were in this 3.8-km^2 area (Fig. 4).

Very little commercial dredging had been done in Shelburne Harbour by the time Libby departed in May 1971; however, he felt "from all reports from the boat skippers it appeared that this area would yield by far the most clams of any of the areas sampled. Sizes were in the large cherry and chowder group." Haughton stated that he "caught as many as 260 bu/d in Shelburne Harbour, and in 5 d took 1100 bu. The abundance had not dropped off seriously and there would be enough clams in this harbor to keep a plant operating at this rate for 2 yr." From these catch rates, we estimated an abundance of 12.1 x 10^6 quahaugs for the 1.2-km^2 Lower Sandy Point bed alone (Fig. 3G). An observer, Lauchie Meagher, joined the BLUE SWAN for a day of commercial fishing on this bed and his comments are appended (Appendix II).

One sediment sample was taken by SCUBA on the test area in 1971 where hard-packed sand predominated. The median grain size was 2.4 Ø, much the same as that found on the main commercial bed in Medway Channel. Nine sediment samples were taken in 1972. The median particle size ranged from 2.4 Ø near the test area to 3.9 Ø on silt at the northern end of the transect (Table 2).

AREA VIII - SHAG HARBOUR

Emerson Smith of Cape Sable Island suggested several locations to fish here and nine tows were made (Fig. 3H) in much the same area of hard-packed sand bottom as that sampled by dry dredge in May 1969 (Medcof et al. 1969). Strong tides, deep water (av. 17.9 m), and high winds made towing very difficult and catches were a poor reflection of what was there. Several tows produced good catches (1162 quahaugs were caught in tow 21). Quahaugs were small with a light brown or beige periostracum and should be acceptable for the half shell trade. Length frequencies determined for three tows showed a narrow size range and a mode at 55-59.9 mm, very similar to the frequency found in Seal Cove (Fig. 5A) during preliminary trials.

SUMMARY

Ocean quahaugs were abundant in several inlets along the south shore and most beds were on sand bottom which appeared quite barren of other fauna.

La Have River estuary: estimated abundances were 46.6 x 10^6 for 6.3 km^2 and 107.8 x 10^6 for 7.7 km^2 for the 1972 and Libby surveys, respectively; density increased toward the head of the estuary where the greatest quahaug population of the survey occurred; a single mode length frequency was at 80-89.9 mm with the largest quahaugs of the survey being found here; bottom varied from coarse sand and gravel near the entrance to silt near the head of the estuary; depth of tows were from 15.2-6.1 m with most at 7-7.5 m; area closed to shellfish harvesting due to pollution.

False La Have: estimated abundances were 5.9 x 10^6 for 1.3 km^2 and 21.1 x 10^6 for 1.4km^2 for the 1972 and Libby surveys, respectively; densities were highest in mid channel and towards the eastern shore; length frequency showed sharp mode at 65-69.9 mm with quahaugs being similar in size throughout area; bottom was rocky at entrance, sand and silty sand in the middle and silt at the head of the inlet; shallow inlet with most tows at 3.7 m depth; area was heavily exploited the year before our survey.

Green Bay: not included in our survey; commercially exploited along the eastern side of the bay in 9-11 m where abundances for a 1.4-km^2 bed were estimated at 8.8 x 10^6 quahaugs; very large quahaugs were fished on sand bottom; surf clams were found at low tide along Crescent Beach.

Medway Harbour: not included in our survey; observations were made on commercial fishing and gear efficiency; quahaug abundances were estimated at 63.8 x 10^6 for 4.4 km^2 and 5.6 x 10^6 for 1.0 km^2 for Libby's survey and commercial data, respectively; length-frequency mode of commercial catch was 80-89.9 mm.

Outer Liverpool Bay: unable to survey here due to depth restrictions of the research dredge and hard bottom; very small quahaugs caught here by commercial dredge; Libby sampled area near Sow and Pigs ledge and found high density of small quahaugs.

Jordan Bay: attempted to survey here with the dry "Bush" dredge and caught very few; hard-packed sand bottom precluded proper fishing with this dredge.

Shelburne Harbour: density was high at the entrance, in mid-channel, and towards the eastern side of the Eastern Way; abundances were estimated at 65.3 x 10^6 for 9.9 km^2 and 12.1 x 10^6 for 1.2 km^2 for the 1972 survey and commercial data, respectively; sizes varied depending on location, small quahaugs (40-44.9 mm) were mostly on the northern part of the transect, with a mixture of medium and large (two modes at 70-79.9 and 95-99.9 mm) on the 11-m deep Lower Sandy Point bed; mostly hard-packed sand bottom becoming muddy to the north and west of the transect; depth of tows averaged 9.4 m; Libby's survey in Western Way was mostly in 12 m and showed high concentrations with an estimated abundance of 59.7 x 10^6 for 3.8 km^2; growth rates at Shelburne were faster than that found for Northumberland Strait.

Shag Harbour: density was estimated to be moderately high and shell lengths were small (55-59.9 mm); depth was greater than other inlets surveyed (av. 17.9 m); bottom was hard-packed sand; there was no commercial fishing in this area although it showed promise.

GENERAL COMMENTS AND CONCLUSIONS

Our quahaug density estimates (mean = 5.6/m^2) were much lower than those reported by Libby (mean = 14.8/m^2), but only slightly less than those estimated from commercial data (mean = 7.3/m^2). Quahaug fishing with hydraulic gear is a precise operation, and tow speed must be well coordinated with the digging rate of the dredge if it is to perform efficiently. The HARENCUS was too large and insensitive for our small hydraulic dredge and often towing speed could not be controlled due to strong winds and/or excessive water currents. Even after

allowances are made for dredge inefficiency, it would be expected that densities estimated from our survey would be less than those estimated from commercial data as they fished only on highly populated beds.

SCUBA is a very effective survey technique for a sedentary species such as ocean quahaugs, especially in shallow-water areas. However, it should be noted that Libby may have biased his counts when he attempted "to pick an average looking spot" by inducing quahaugs to reveal their position prior to laying his grid on bottom.

The digging blade on our hydraulic dredge was too shallow (13 cm). SCUBA observations revealed that quahaugs were deeper in the soil than we anticipated and the dredge would likely have functioned more efficiently if the blade had been at least 17 cm deep. By rapidly moving a hand back and forth over a small area for several minutes, a diver was able to displace sand inside a 1/4-m^2 quadrant where 16 quahaugs were uncovered without disturbing them. Most were 2.5 cm under the surface; however, approximately one-third of them were buried up to 7.5 cm deep. With some shell lengths reaching 10 cm and buried up to 5-6 cm, the lower shell margin would be deeper than the dredge could dig. It was noted as well that not all quahaugs were in a "siphon-up" position. Three of the 16 clams were "hinge-up" which Libby felt to be the position taken when they were not feeding. He observed when diving during calm weather and in moderate currents that quahaugs would be feeding but, if it was stormy or in areas of strong currents, they would not feed. He noted that they did not seem to be any deeper in the sand and the only difference was in the attitude of the shell, "when not feeding they would be vertical in the sand, the shell opening pointed downward with the hinge line upward; when feeding the shell would be cocked at an angle so the siphon could be aimed at the surface."

Most quahaug beds were in depths from 7-11 m. Libby found that quahaugs were most abundant in the western lee of a land mass where the bottom was a medium grained sand and currents were moderate. Sow and Pigs ledge was an exception as were the quahaug sizes found there. Generally, he found populations within an inlet to be fairly uniform in size. The largest quahaug found by Libby was 4.9 in. (12.5 cm) long.

Quahaugs from Shelburne were studied for growth rates. Annulus heights were measured (Table 7) and a curve was fitted by eye (Fig. 6). Growth in Shelburne Harbour was faster than that for Northumberland Strait (Chandler 1965) and nearly identical to that found in Passamaquoddy Bay (Meagher and Medcof 1972). Slow growth in quahaugs indicates that caution should be used by industry when exploiting stocks. Mendelson et al. (1970) estimated that New England stocks could be replenished to the size-class desired by that industry in 10 yr. The Medway fishery relied mainly on cherrystone and chowder quahaugs, that is, quahaugs with shell lengths in excess of 64 mm. Shelburne growth rates indicated it would take 16 yr or more for stocks to reach that preferred size.

Examination of a quahaug sample for spawning condition in mid July 1971 from Shag Harbour showed that 50% had running spawn. In 1970, Triton Sea Products reported that spawning created a production problem during July and most of August, but that it cleared up by the end of August.

Ocean quahaugs were abundant in a number of shallow, well protected inlets along the south shore of Nova Scotia and could support a limited fishery. Bissell (1972), when speculating upon the brevity of the Medway-based fishery, concluded that "the economics of fishing, processing, and marketing ... were not a significant factor in the decision to cease operations." It would seem that a successful fishery could be developed once again.

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Table 1. M.V. HARENGUS tow and catch records, July 1971.

Date	Area	Tow	Tow length (min)	Depth (m)	Gear type	Length(m) Rope	Length(m) Hose	Water press. kg/cm²	Water press. PSI	Bottom type	Catch (bu)[a] Whole	Broken	Total	Catch (no.) W	B	T	% broken	Remarks
July 6	Shelburne	1	15	9.1	Hyd.	27.4	45.7	2.8	40	h.sand[b]	0.0	0.0	0.0	0	0	0	-	Tow too fast
" "	"	2	20	7.3	"	22.9	"	"	"	"	1.25	0.5	1.75	329	109	438	25	Towed beside Blue Swan
" "	"	3	24	7.3	"	22.9	"	3.5	50	mud	0.0	0.0	0.0	0	0	0	-	
" "	"	4	20	9.1	"	27.4	"	"	"	sand	2.0	0.3	2.3	554	31	585	5	
" "	"	5	20	6.1	"	18.3	30.5	2.8	40	mud	0.25	0.0	0.25	30	1	31 est.	3	Breakage low on soft bottom
" "	"	6	20	7.6	"	22.9	45.7	"	"	mud	0.75	0.0	0.75		0	300	0	
July 7	"	7	10	9.1	"	27.4	"	3.1	45	h.sand	0.2	0.1	0.3	52	19	71	27	54.4 kg weight added to dredge
" "	"	8	15	10.0	"	"	"	2.8	40	"	1.5	0.25	1.75	496	51	547	9	Will be our test area
" "	"	9	-	10.0	"	"	"	"	"	"	-	-	1.3	297	102	399	26	In our test area
July 12	Jordan Bay	10	10	7.3	Bush	-	-	-	-	s.sand[c]	0.0	0.0	0.0	0	0	0	-	
" "	" "	11	10	7.3	"	-	-	-	-	"	-	-	-	11	1	12	9	
" "	" "	12	10	12.8	"	-	-	-	-	"	0.0	0.0	0.0	0	0	0	-	
" "	" "	13	10	-	"	-	-	-	-	s.rock[d]	-	-	-	0	0	1	-	
" "	" "	14	10	15.5	"	-	-	-	-	catchy	-	-	-	-	-	-	-	Dumping gate opened
" "	" "	15	5	15.5	"	-	-	-	-	"	0.0	0.0	0.0	0	0	0	-	Repeated #14
July 14	Shag Hbr.	16	-	16.5	Hyd.	53.3	76.2	2.8	40	h.sand	0.8	0.2	1.0	608	47	655	7	
" "	" "	17	10	17.5	"	"	"	"	"	"	-	-	-	6	0	6	0	Strong current, towed too fast
" "	" "	18	12	16.5	"	"	"	"	"	"	-	-	0.25	77	13	90	14	
" "	" "	19	-	18.0	"	"	"	3.5	50	"	-	-	-	-	-	-	-	Parted hose, aborted tow
July 15	" "	20	10	17.5	"	"	"	2.8	40	"	-	-	0.75	426	40	466	9	Small quahaugs
" "	" "	21	15	20.0	"	"	"	"	"	"	1.75	0.25	2.0	1064	98	1162	8	1 bu[a] empty shells
" "	" "	22	27	16.5	"	"	"	"	"	s.rock	0.0	0.0	0.0	0	0	0	-	Dredge not towing well
" "	" "	23	10	16.5	"	"	"	"	"	"	-	-	-	7	1	8	14	Dredge not towing well
" "	" "	24	10	22.0	"	"	"	"	"	"	0.0	0.0	0.0	0	0	0	-	Dredge not towing well

[a] 1 bu = .035 m^3.

[b] Hard-packed sand.

[c] Silty sand.

[d] Small rocks.

Table 2. M.V. HARENGUS tow and catch records, May 1972.

Date	Area	Tow	Tow length (min)	Tow length (m)	Depth (m)	Gear type	Length (m) Rope	Length (m) Hose	Water press. kg/cm²	Water press. PSI	Catch (bu)[a]	Catch (no)	Density (#/m²)	Bottom type	Median grain size (ϕ)	Remarks
May 13	La Have	25	2	37	7.3	Hyd.	18.3	30.5	2.8	40	2.0	310	20.4	catchy	1.3	Broke tow rope, caught on bottom
" "	"	26	-	183	"	"	"	"	"	"	2.25	369	4.9		2.5	Smooth bottom
" "	"	27	5	60	"	"	"	"	"	"	2.5	645	26.2		3.0	
" "	"	28	13	183	"	"	"	"	"	"	0.7	93	1.2	sticky mud	-	
" "	"	29	13	"	"	"	"	"	3.5	50	0.25	51	0.7	" "	-	
" "	"	30	14	"	6.1	"	"	"	2.8	40	-	6	0.1	mud	2.7	Lot of dead shell
" "	"	31	13	"	"	"	"	"	"	"	-	6	0.1	"	-	Duplicate of #30
" "	"	32	11	"	15.2	"	45.7	61.0	"	"	-	2	0.03	small rocks	2.4	
" "	"	33	10	"	"	"	"	"	3.5	50	-	6	0.1	" "	-	Duplicate of #32
May 14	False La Have	34	10	"	7.3	"	22.9	30.5	2.8	40	0.9	119	1.6	mud	2.6	
" "	" "	35	11	"	"	"	"	"	"	"	0.5	112	1.5	sand, mud	-	Duplicate of #34
" "	" "	36	11	"	6.4	"	18.3	"	"	"	0.9	202	2.7	small rocks	2.5	Few small rocks in dredge
" "	" "	37	11	"	"	"	"	"	"	"	1.3	302	4.0	" "	-	Duplicate of #36. Clean tow
" "	" "	38	17	"	6.1	"	"	"	"	"	0.6	175	2.3	mud, rocks	0.8	
" "	" "	39	15	"	"	"	"	"	"	"	1.2	374	5.0	" "	0.5	Duplicate of #38
" "	" "	40	10	"	7.9	"	22.9	"	"	"	-	7	0.1	coarse sand	1.8	
" "	" "	41	10	"	"	"	"	"	4.2	60	-	5	0.1	sand	0.7	Duplicate of #40
" "	" "	42	13	"	6.1	"	18.3	"	2.8	40	4.0	1080	14.4	mud, sand	2.2	
" "	" "	43	12	"	"	"	"	"	"	"	2.2	608	8.1	" "	-	Duplicate of #42. Sand dollars
May 15	" "	44	10	"	6.1	"	"	"	"	"	1.0	271	3.6	" "	-	Sand dollars
" "	" "	45	11	"	"	"	"	"	"	"	1.1	332	4.4	sand	-	Duplicate of #44
" "	" "	46	10	"	5.2	"	"	"	"	"	0.25	56	0.8	"	1.6	Sand dollars, clean catch
" "	" "	47	10	"	"	"	"	"	"	"	0.9	202	2.7	"	-	Duplicate of #46.
" "	" "	48	10	"	7.0	"	"	"	"	"	0.5	100	1.3	"	1.4	
" "	" "	49	10	"	"	"	"	"	"	"	0.5	100	1.3	"	-	Duplicate of #48, some spawn
" "	" "	50	10	"	7.3	"	"	"	"	"	0.4	82	1.1	"	2.4	
" "	" "	51	11	"	"	"	"	"	4.2	60	1.1	221	2.9	mud	2.5	Duplicate of #50
" "	" "	52	11	"	5.5	"	"	"	2.8	40	-	6	0.1	black mud	3.9	
" "	" "	53	16	274	5.8	"	18.3	30.5	2.8	40	1.7	441	3.9		2.2	
" "	" "	54	11	183	"	"	"	"	"	"	2.0	504	6.7			Duplicate of #53. Clean catch
May 17	Liverpool	55	30	-	27.4	Dry	-	-	0	0	-	-	-	sand, rock		Dredge did not dig in (3 attempts here)
May 18	Shelburne	56	8	137	18.3	Hyd.	36.6	76.2	2.8	40	2.8	1122	20.0	h. sand	2.7	Tow rope broke
" "	"	57	13	183	10.7	"	27.4	45.7	"	"	4.3	944	12.6	" "	2.4	
" "	"	58	14	"	9.1	"	"	"	"	"	0.9	245	3.3	" "	2.6	Dredge not fishing properly
" "	"	59	12	"	"	"	"	"	"	"	2.0	544	7.3	" "		Duplicate of #58
" "	"	60	11	"	"	"	"	"	"	"	1.2	199	2.7	mud	3.0	Strong odor to mud
" "	"	61	10	"	7.6	"	22.9	30.5	"	"	-	11	0.1	"	2.6	Sand dollars
" "	"	62	12	"	6.1	"	18.3	"	"	"	0.3	57	0.8	sand	3.1	
" "	"	63	11	"	"	"	"	"	3.5	50	2.0	331	4.4	"	-	Repeat #62
" "	"	64	-	"	7.0	"	"	"	2.8	40	-	5	0.1	mud	3.8	Light brown clams
" "	"	65	11	"	11.0	"	30.5	45.7	"	"	0.2	51	0.7	mud	3.9	Light brown clams

[a] 1 bu = .035 m³.

Table 3. Ocean quahaug catch rates (#/tow) and densities (#/m^2) for the dredge surveys and Libby's SCUBA survey.

Hydraulic Dredge Surveys

Year	Area	# tows	Catch rate (#/tow) min.	max.	mean	Density (#/m) min.	max.	mean
1971	Shelburne (E.W.)[a]	9	0	585	263.4	-	-	-
	Jordan Bay	6	0	12	2.6	-	-	-
	Shag Harbour	9	0	1162	298.4	-	-	-
1972	La Have River	9	2	1533.2	448.2	.03	26.2	6.0
	False La Have	21	5	1080	245.3	.1	14.4	3.6
	Liverpool	1	-	-	-	-	-	-
	Shelburne (E.W.)	10	5	1499	388.6	.1	20.0	5.3

Libby's SCUBA Survey

Area	# dives	#/yd min.	max.	mean	#/m min.	max.	mean
La Have River	10	0	32	8.2	0	38.3	9.8
False La Have	17	0	28	9.6	0	33.5	11.5
Medway Harbour	10	0	18	9.7	0	21.5	11.6
Shelburne (E.W.)	1	-	-	3	-	-	3.6
(W.W.)[a]	8	7	20	13.1	8.3	23.9	15.7

[a](E.W.) = Eastern Way
(W.W.) = Western Way

Table 4. Estimated abundance of ocean quahaugs for areas where quahaugs occurred, for 1) the 1972 dredge survey (1972), 2) Libby's survey (L.), and 3) commercial fishing data (C.).

Area	Mean density (#/m^2) 1972[a]	L.	C.	Populated area (km^2) 1972	L.	C.	Est. adundance ($x10^{-6}$) 1972	L.	C.
La Have River	7.4	14.0	-	6.3	7.7	-	46.6	107.8	-
False La Have	4.5	15.1	-	1.3	1.4	-	5.9	21.1	-
Green Bay	-	-	6.2	-	-	1.4	-	-	8.8
Medway Harbour	-	14.5	5.6	-	4.4	1.0	-	63.8	5.6
Shelburne (E.W.)	6.6	-	10.1	9.9	-	1.2	65.3	-	12.1
(W.W.)	-	15.7	-	-	3.8	-	-	59.7	-

[a]Densities for 1972 from Table 3 were prorated (x 1.24) to offset dredge inefficiency.

Table 5. Salinities and water temperatures taken during the HARENGUS survey 1972.

Date	Area	Tow #	Salinity (o/oo)		Temp. (°C)	
			Surface	2.4-m depth	Surface	Bottom
May 13	La Have	25	19.74	22.14	-	4.6
May 14	False La Have	35	28.60	28.49	5.6	3.6
May 17	Liverpool	55	-	-	6.5	5.8
May 18	Shelburne	56	25.41	27.25	9.7	4.4
		57	-	-	9.4	4.4
		65	16.42	16.58	13.0	5.2

Table 6. Ocean quahaug mean and modal length frequencies for samples from A. HARENGUS survey and B. BLUE SWAN, 1971-72.

Area	Total #	Shell length (mm)	
		Mean	Modal
A. Research samples			
La Have, 1972	806	79.4	80-84.9
False La Have, 1972	1436	72.8	70-74.9
Shelburne, 1972	654	74.3	65-69.9
Shelburne, 1971	855	76.8	75-79.9
Shag Harbour, 1971	762	59.6	55-59.9
Seal Cove, 1971	477	55.5	55-59.9
B. Commercial samples			
Shelburne, 1971	203	83.5	70-79.9 and 95-99.9
Medway, 1971	185	80.1	80-84.9

Table 7. Growth rates (height of annulus (mm)) of ocean quahaugs from the Shelburne Harbour HARENGUS survey, 1972.

No. of annuli	Shell height	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
7	47.8	6.4	9.1	20.0	27.8	35.3	38.1	43.2											
8	46.2	6.0	13.6	17.8	21.6	25.0	32.7	38.9	43.3										
10	53.8	9.4	14.1	19.6	24.5	29.4	33.9	38.2	42.6	47.2	51.2								
11	57.1	6.6	11.8	14.9	19.2	24.3	29.3	34.3	40.2	44.5	48.3	52.9							
11	55.9	5.9	11.8	19.8	24.0	29.2	34.6	39.7	45.0	48.1	50.5	52.9							
13	57.6	8.9	11.6	21.7	26.9	29.8	36.7	39.7	43.6	46.0	49.2	51.5	53.7	55.4					
14	59.4	7.3	12.0	16.7	25.1	31.6	36.5	41.5	43.2	46.6	49.5	53.4	55.2	57.0	58.4				
14	62.2	9.0	13.2	18.1	23.4	28.1	36.1	40.5	43.5	46.6	49.8	51.4	54.7	57.7	60.2				
15	59.8	8.1	12.0	19.4	22.2	27.2	29.7	33.3	37.1	41.2	43.8	46.5	49.9	52.7	55.1	56.3			
18	80.7	9.0	13.6	18.2	21.4	26.8	31.0	38.7	46.6	54.1	58.0	61.0	63.5	65.8	68.7	70.4	72.3	75.4	78.2
18	71.5	9.2	16.0	21.4	33.3	37.3	39.5	43.6	46.7	48.7	50.7	52.8	55.6	58.5	61.4	63.9	65.7	68.4	70.0
av.	59.3	7.8	12.6	18.9	24.5	29.5	34.4	39.2	43.2	47.0	50.1	52.8	55.4	57.9	60.8	63.5	69.0	71.9	74.1

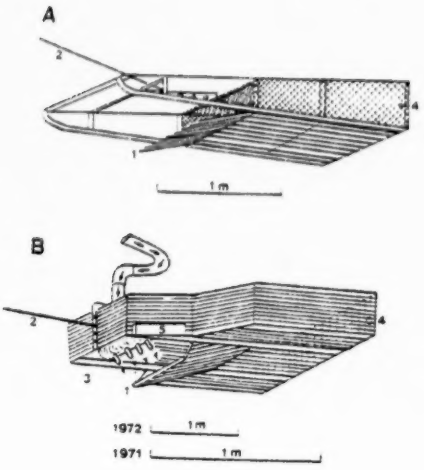

Fig. 1. A. Bush dry dredge; B. hydraulic dredge.

1. Teeth (joined by lip in hydraulic dredge).
2. Tow point
3. Manifold
4. Dumping door
5. Lead "bricks" to regulate dredge weight.

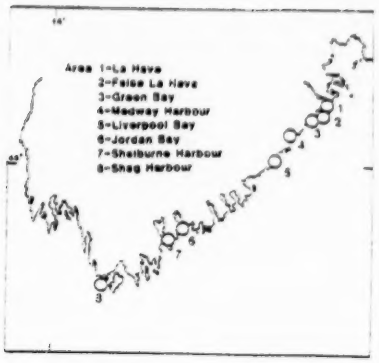

Fig. 3. Areas surveyed along the south shore of Nova Scotia, 1971-72.

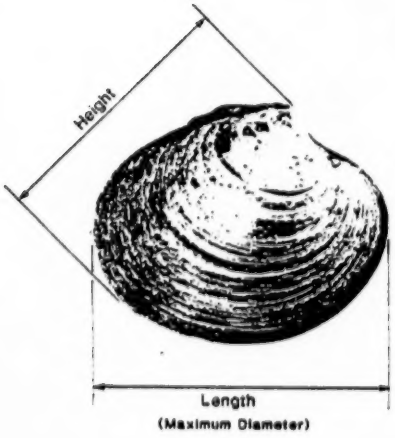

Fig. 2. Ocean quahaug (Arctica islandica) showing measurement axes.

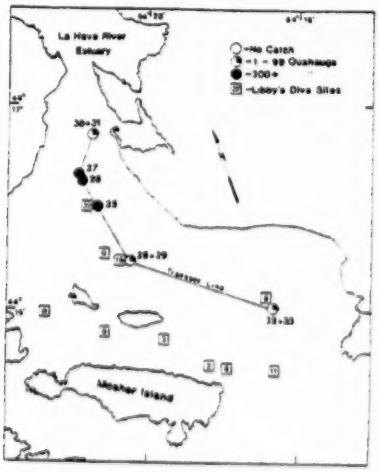

Fig. 3A. Positions of tows made in La Have River estuary, 1972, and locations of Libby's dive sites with densities (#/yd^2).

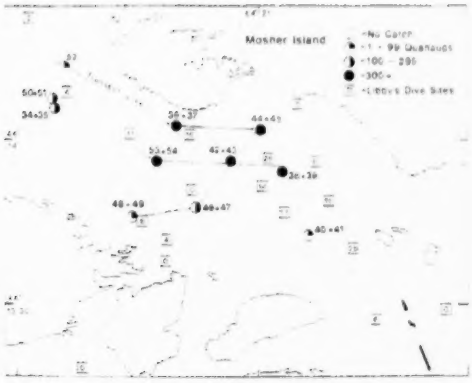

Fig. 3B. Positions of tows made in False La Have, 1972, and locations of Libby's dive sites with densities (#/yd^2).

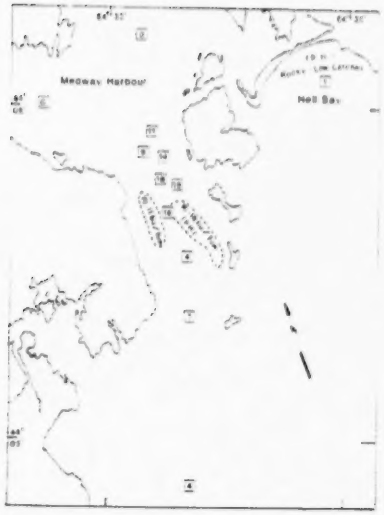

Fig. 3D. Locations of commercial quahaug beds in Medway Harbour and positions of Libby's dive sites with densities (#/yd^2).

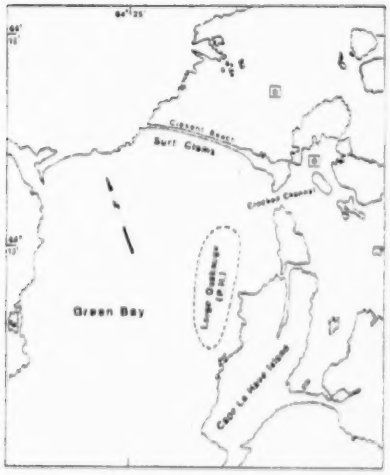

Fig. 3C. Location of commercial bed of large quahaugs in Green Bay and locations of Libby's dive sites (2).

Fig. 3E. Positions of tows made outside Liverpool Bay, 1972, Libby's dive sites (4), and areas commented on by Haughton.

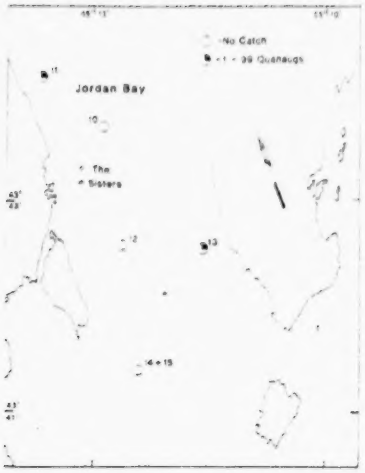

Fig. 3F. Positions of tows made in Jordan Bay, 1971.

Fig. 3H. Positions of tows made in Shag Harbour, 1971.

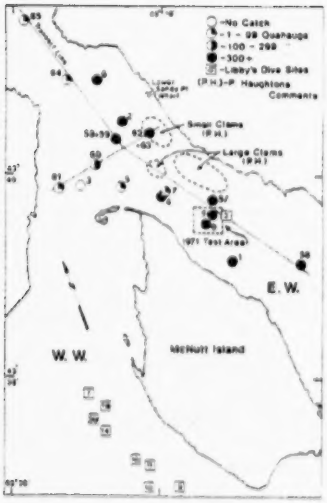

Fig. 3G. Positions of tows made in Shelburne Harbour, 1971 (#1-9) and 1972 (#56-65), and locations of Libby's dive sites with densities (#/yd^2). (The Lower Sandy Point bed is identified by a dashed line.)

Fig. 3I. Positions of tows during gear trials at Seal Cove, 1971.

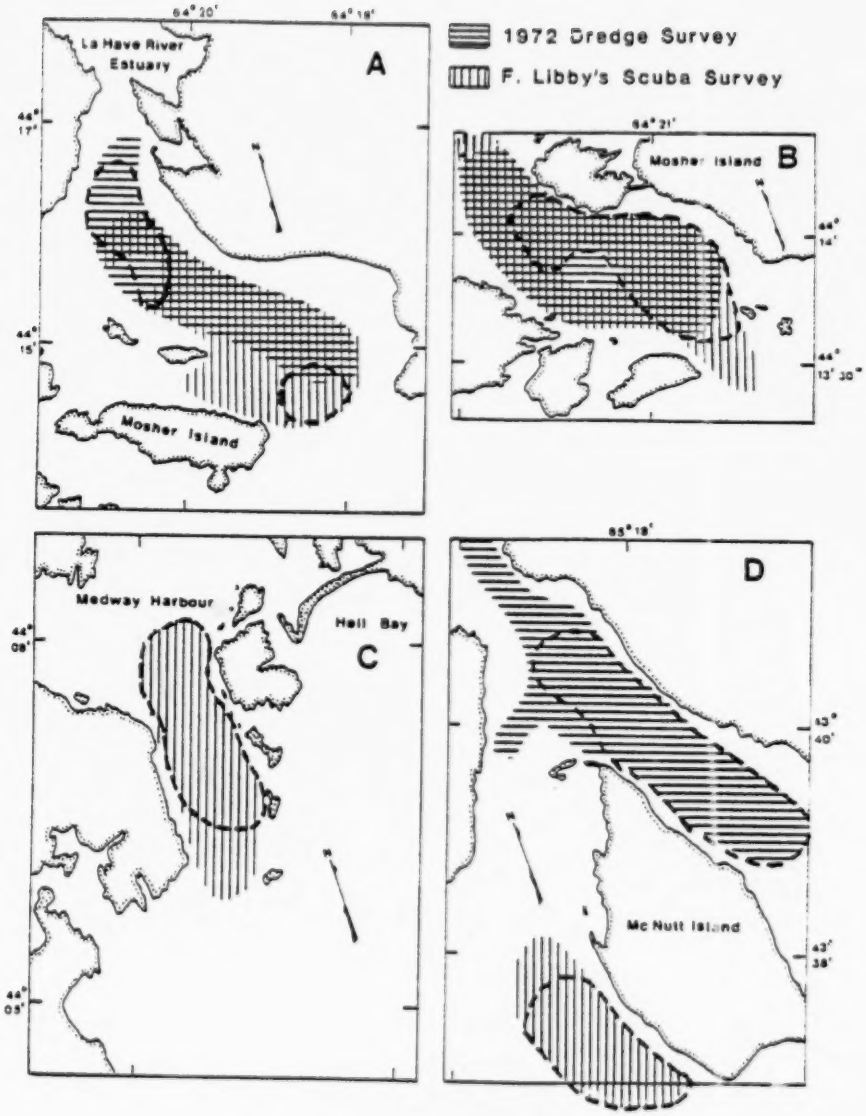

Fig. 4. Areas where ocean quahaugs were found during the 1972 HARENGUS survey and Libby's survey in a) the La Have River estuary; b) False La Have; C)Medway Harbour; and D) Shelburne Harbour. (Areas of commercial concentrations are outlined with a dotted line.)

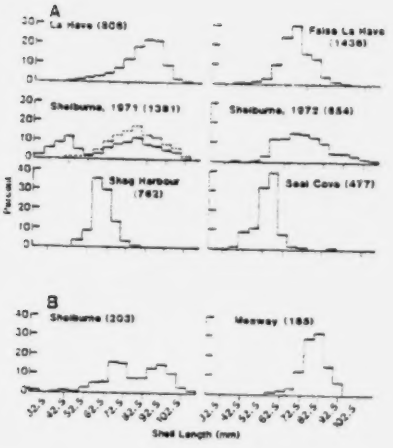

Fig. 5. A. Length frequencies of ocean quahaugs taken during the HARENGUS survey.

B. Length frequencies of ocean quahaugs taken by the commercial dredger, BLUE SWAN, 1971.

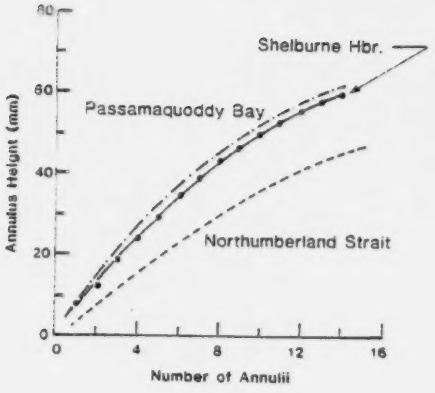

Fig. 6. Growth rates for ocean quahaugs from Shelburne Harbour, compared to Passamaquoddy Bay and Northumberland Strait.

Appendix I. Breakage at dumping - Shelburne, July 9, 1971

by J. C. Medcof

200 whole clams were carefully placed in the hydraulic dredge cage and dumped from a height of 18 in. (45.7 cm) between deck and tailgate.

Count after dumping - 16 broken.

12 of the 16 were broken at the thickest part of the animal i.e. high on the shell below the umbones. The cracks in the shell radiated from this point.

3 had their hairline breaks near the perimeter of the shell, 1 had a damaged lip.

Lengths (greatest diameters) of these 16 were: 69, 74, 83, 67, 90, 79, 71, 77, 52, 68, 70, 60, 77, 71, 61, 74

The shells were as brittle as glass. The 8% dumping breakage was not surprising.

Breakage in catch of hydraulic sampler before dumping, Shelburne, 1971.

		Whole clams			Broken clams		
Sample no.	Total catch whole + broken	Count AD[b]	Est. no.[a] BD[c]	Est. no. BD total catch	Count AD [(1)-(2)]	Est. no. BD [(1)-(3)]	Est. no. BD total catch [100-(4)]
	No. (1)	No. (2)	No. (3)	% (4)	No. (5)	No. (6)	% (7)
1	438	303	329	75	135	99	25
2	585	510	554	95	75	31	5
3	32	31	34	106	1	- 2	0
4	71	48	52	73	23	19	27
5	547	456	496	91	91	51	9
6	399	273	297	74	126	102	26
7	559	408	444	79	151	115	21
8	681	515	560	82	166	212	18
9	587	396	430	73	191	157	27
10	643	491	534	83	152	109	17
				Av. 83%			17%

[a] = count of whole AD x $\frac{100}{92}$

[dumping breakage = 8%]

[b] AD = after dumping

[c] BD = before dumping

Appendix II. Observations aboard the commercial dredger, M.V. BLUE SWAN, Shelburne, July 12, 1971

by L. Meagher

Hydraulic dredger

Length - 65' (19.8 m)
Main engine - 165 HP (167.3 HP (metric))

Pump-motor assembly for hydraulic dredge

Motor - 100 HP (101.4 HP (metric)) diesel
Pump - 750 gal/min @ 60 lb psi (2838.8 L/min @ 4.2 kg/cm^2)
Hose - intake and outlet were both 6" (15.3 cm) inside diam.

Test dredge (BLUE SWAN)

This is a dry dredge 9' x 3' (2.7 m x 0.9 m) used for exploring and not aboard BLUE SWAN now. Its teeth are like those on the BLUE SWAN's hydraulic dredge. It is hard to tow at an even speed as it jumps and starts and quickly fills with mud and sand. It never took more than 1-2 bu (0.04-0.07 m^3) even in 40-min tows on the best grounds, and it broke about one third of the catch.

Tows and towing site

According to Capt. Paul Haughton, the BLUE SWAN averages 10-11 tows per day with catches between 20-30 bu (0.7-1.1 m^3). On July 12, 11 tows of 15- to 20-min duration were made for a total catch of 198 bu (6.9 m^3) (av. 18 bu (0.6 m^3)). Observations were made on the last five tows (see table at end of this appendix). It is common practice to tow with the tide; however, as the wind was blowing NW 25-30 mph (40.2-48.3 km/h), the BLUE SWAN towed with the wind. With these strong onshore winds tows were made about 400 yd (365.8 m) offshore in 6 fath (11 m). In calm weather they would be closer to shore. Much the same starting point was used for each tow. All tows were made on the lower end of the Lower Sandy Point bed which extends from the Lower Sandy Point government wharf for one nautical mile paralleling the shore.

When the dredge was boarded for dumping, its tailgate usually came to rest on the deck with only a very slight jolt that seemed unlikely to cause any breakage to the clams inside. When the tailgate was opened, the quahaugs flowed gently out onto the deck. As nearly as could be determined, there was no dumping breakage such as we experienced in early stages of our July 6-10 tests.

Sediment character

According to Haughton, the sediment in this area has a strong odor and is coarser than in most other ocean clam beds in Shelburne Harbour. In general, it is hard-packed sand. The Medway Harbour beds are similar, but the Green Bay grounds are softer with considerably more silt mixed in with the sand.

Clams

Haughton said the average size of the usable clams runs small in Medway Harbour, intermediate in Shelburne Harbour and large in Green Bay. Large sizes are commercially more desirable because the per pound processing costs are less. If Green Bay beds were more densely stocked, BLUE SWAN would work them more often.

A random sample (203 clams) from the pooled catches of tows #1 and #2 was measured for size composition (Fig. 4B, Appendix Table 1G). The periostracum of most clams was eroded and white shell was exposed in the umbone region of most clams. Haughton attibutes this to abrasion by the coarse sandy sediment.

Haughton felt natural mortality may be heavier in Shelburne Harbour than in Medway Harbour and Green Bay since moribund and dead, rotting clams are commonest in Shelburne. Such clams were found in bushel-box samples of the catch and were discarded as "trash." For example, of the 162 quahaugs in the tow 1 sample, six or seven were rotten, equivalent to 4% of the count of living clams.

The odor of these clams, which were sometimes in a semi-liquid state, was strong and repulsive and may be responsible for the strong smell of the soil mentioned by Haughton. We encountered clams in this state during our July 6-10 trials and attributed their deaths to dredge damage. However, Haughton attributed many of their deaths to natural mortality because most shells were still intact.

Haughton stated that Shelburne clams do not keep well in their shells when stored in air. He interpreted this, along with the high incidence of moribund clams on the beds, as evidence of poor condition of animals in Shelburne Harbour.

Appendix II (cont'd)

Deficiencies of our hydraulic dredge

Haughton suggested that our cutting blade should be set deeper to reduce breakage of the catch. He suggested 7 1/2 in. (19 cm) as a good depth for large clams such as are regularly taken in Shelburne.

He felt we should do away with the lip blade and replace it with long, strong, separate teeth. The first dredge he used had a blade but seemed inefficient in capturing clams. He replaced this with separate teeth and claims that capture rate increased greatly - possibly by as much as 75%. He felt our pump-motor assembly would supply a larger dredge with a wider mouth.

Data on bushel-box samples from the unsorted catch of 5 tows for ocean clams with a commercial hydraulic dredge in Shelburne Harbour, N.S., by M.V. BLUE SWAN, July 12, 1971.

Tow #	Catch (bu)	Catch (m^3)	Clams in sample #	Whole No.	Whole %	Broken No.	Broken %	Comments
7	28	1.0	162	136	84	26	16	1/2 bu (0.02 m^3) trash in sample, 6 rotting clams
8	16	0.6	104	78	75	26	25	Strong smell to the soil
9	16	0.6	159	136	86	23	14	1/2 bu (0.02 m^3) trash in sample, fewer rotten clams than tows 1 and 2
10	26	0.9	145	125	86	20	14	Fewer rotten clams
11	-		142	108	76	34	24	Last tow of day. strong smell on this tow
Av	22	0.8	144	-	82	-	18	

Appendix Table 1A. Ocean quahaug shell length frequencies for La Have River Estuary, 1972.

Shell length (mm)	Tows									Total	
	25	26	27	28	29	30	31	32	33	#	%
0-4.9											
5-9.9											
10-14.9											
15-19.9											
20-24.9											
25-29.9											
30-34.9											
35-39.9											
40-44.9			1							1	0.1
45-49.9	1		4	2	1					8	1.0
50-54.9		2	9		1			2	1	15	1.9
55-59.9	4	3	6	8	2					23	2.8
60-64.9	4	10	11	1	3		1		1	31	3.8
65-69.9	14	11	16	10	2	2			2	57	7.1
70-74.9	21	26	20	14	5				1	87	10.8
75-79.9	52	37	33	15	7				1	145	18.0
80-84.9	86	51	19	8	8		2			174	21.6
85-89.9	91	42	6	20	9	2	2			172	21.3
90-94.9	33	19	3	8	9		1			73	9.1
95-99.9	4	2		6	3	1				16	2.0
100-104.9				1	1	1				3	0.4
105-109.9		1								1	0.1
110-114.9											
Total	310	204	128	93	51	6	6	2	6	806	100

Appendix Table 1B. Ocean quahaug shell length frequencies for False La Have, 1972.

Shell length (mm)	Tows															Total	
	34	35	36	37	38	39	40	41	42	44	46	48	50	52	53	No.	%
0-4.9																	
5-9.9																	
10-14.9																	
15-19.9																	
20-24.9																	
25-29.9																	
30-34.9																	
35-39.9																	
40-44.9					1											1	0.1
45-49.9					1											1	0.1
50-54.9	2	1		1	2					4						10	0.7
55-59.9	2	6	1	1	1	6			2	11		1	1	1	2	35	2.4
60-64.9	19	13	8	6	22	15			7	32	1	3	4		8	138	9.6
65-69.9	17	22	31	24	47	48	3		39	48	4	8	15		30	336	23.4
70-74.9	34	34	40	20	62	61	3	1	47	36	11	12	14	1	53	429	29.9
75-79.9	27	22	19	9	6	24		1	24	5	18	32	18	2	15	222	15.5
80-84.9	15	11	17	32	3	1	1		11	11	16	35	24	1	12	190	13.2
85-89.9	2	3	8	12		1		2	3	2	5	7	5	1	5	56	3.9
90-94.9			2	6				1	2	1	1	2	1			16	1.1
95-99.9					1					1						2	0.1
100-104.9																	
105-109.9																	
110-114.9																	
Total	118	112	126	111	146	156	7	5	135	151	56	100	82	6	125	1,436	100

Appendix Table 1C. Ocean quahaug shell length frequencies for Shelburne Harbour, 1971.

Shell length	Tows					Total		Total (exclude 6)	
(mm)	2	4	5	6[a]	9	No.	%	No.	%
0-4.9									
5-9.9				6		6	.4		
10-14.9				6		6	.4		
15-19.9				8		8	.6		
20-24.9				9		9	.7		
25-29.9				32	1	33	2.4	1	0.1
30-34.9	1			83	1	85	6.2	2	0.2
35-39.9			1	116	2	119	8.6	3	0.4
40-44.9		5	1	159	4	169	12.2	10	1.2
45-49.9		3		60	6	69	5.0	9	1.1
50-54.9	1	3	1	15	7	27	2.0	12	1.4
55-59.9	5	11		2	24	42	3.0	40	4.7
60-64.9	5	32		4	40	81	5.9	77	9.0
65-69.9	27	41		10	28	106	7.7	96	11.2
70-74.9	61	31	2	3	27	124	9.0	121	14.2
75-79.9	81	32	8	4	23	148	10.7	144	16.8
80-84.9	55	19	8	1	24	107	7.7	106	12.4
85-89.9	25	25	2	3	41	96	7.0	93	10.9
90-94.9	14	21	2	1	29	67	4.9	66	7.7
95-99.9	20	15	4	2	13	54	3.9	52	6.1
100-104.9	7	7	1	2	3	20	1.4	18	2.1
105-109.9	2		1			3	.2	3	0.4
110-114.9	2					2	.1	2	0.2
Total	306	245	31	526	273	1381	100	855	100.1

[a]Special tow on bed of very young quahaugs.

Appendix Table 1D. Ocean quahaug shell length frequencies for Shelburne Harbour, 1972.

Shell length (mm)	Tows								Total	
	56	57	58	60	61	62	64	65	No.	%
0-4.9										
5-9.9										
10-14.9										
15-19.9										
20-24.9										
25-29.9										
30-34.9										
35-39.9								1	1	0.2
40-44.9										
45-49.9		1	1					1	3	0.5
50-54.9	16	1	1	1					19	2.9
55-59.9	60	4	6	2	1	1		1	75	11.5
60-64.9	61	2	9	4				1	77	11.8
65-69.9	27	10	50	1	1	3		5	97	14.8
70-74.9	17	22	30	5	1	8	1	9	93	14.2
75-79.9	11	19	19	11		13	1	13	87	13.3
80-84.9	6	13	8	12	1	7	1	15	63	9.6
85-89.9	4	20	6	10		9		3	52	8.0
90-94.9	2	7	3	8	2	4		2	28	4.2
95-99.9		3	3	13	4	6			29	4.4
100-104.9		6		10	1	2			19	2.9
105-109.9		1		4		4			9	1.4
110-114.9				2					2	0.3
Total	204	109	136	83	11	57	3	51	654	100

Appendix Table IE. Ocean quahaug shell length frequencies at Shag Harbour (Cape Sable Is.), 1971.

Shell length (mm)	Tows			Total	
	16	18	21	No.	%
0-4.9					
5-9.9					
10-14.9					
15-19.9					
20-24.9					
25-29.9			1	1	0.1
30-34.9					
35-39.9			2	2	0.3
40-44.9			1	1	0.1
45-49.9	14	1	11	26	3.4
50-54.9	50	11	57	118	15.5
55-59.9	127	33	108	268	35.2
60-64.9	83	24	114	221	29.0
65-69.9	48	5	45	98	12.9
70-74.9	11	2	11	24	3.1
75-79.9	2	1		3	0.4
80-84.9					
85-89.9					
90-94.9					
95-99.9					
100-104.9					
105-109.9					
110-114.9					
Total	335	77	350	762	100

Appendix Table 1F. Length frequencies for ocean quahaugs from Seal Cove, Grand Manan, 1971.

Shell length (mm)	Tows 6+7	Tows 8	Tows 12	Total No.	Total %
0-4.9					
5-9.9					
10-14.9					
15-19.9					
20-24.9					
25-29.9					
30-34.9					
35-39.9		5	4	9	1.9
40-44.9	1	30	6	37	7.8
45-49.9	2	28	20	50	10.5
50-54.9	67	79	4	150	31.5
55-59.9	91	92	4	187	39.2
60-64.9	17	14	4	35	7.3
65-69.9	1	2	2	5	1.0
70-74.9		1	2	3	0.6
75-79.9					
80-84.9					
85-89.9			1	1	0.2
90-94.9					
95-99.9					
100-104.9					
105-109.9					
110-114.9					
Total	179	251	47	477	100

Appendix Table 1G. Length frequencies of ocean quahaugs caught by commercial dredger, BLUE SWAN, at Shelburne and Medway, 1971.

Shell length (mm)	Shelburne		Medway	
	No.	%	No.	%
0-4.9				
5-9.9				
10-14.9				
15-19.9				
20-24.9				
25-29.9				
30-34.9	1	0.5		
35-39.9				
40-44.9	1	0.5		
45-49.9	2	1.0		
50-54.9	1	0.5		
55-59.9	5	2.5	2	1.1
60-64.9	10	4.9	4	2.2
65-69.9	11	5.4	6	3.2
70-74.9	31	15.3	22	11.9
75-79.9	30	14.8	53	28.6
80-84.9	15	7.4	59	31.9
85-89.9	15	7.4	27	14.6
90-94.9	25	12.3	12	6.5
95-99.9	29	14.3		
100-104.9	20	9.8		
105-109.9	6	3.0		
110-114.9	1	0.5		
Total	203	100.1	185	100